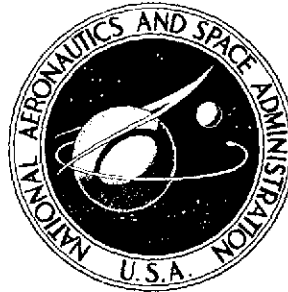


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OF A CESIUM DIMINIODE
WITH RELATIVELY IMPURE
110-TUNGSTEN ELECTRODES**

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and James F. Morris*

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SUMMARY

Thermionic performance data from a miniature plane cesium diode (diminiode, with 110-tungsten electrodes are presented. The diminiode has a guard-ringed collector and a spacing of 0.23 millimeter. The data were obtained by using a computerized acquisition system. The diode was tested at increments between 1700 and 1900 K for the emitter, 694 and 1101 K for the collector, and 519 and 650 K for the reservoir. A maximum power density of 4.5 watts per square centimeter was obtained at an emitter temperature of 1900 K. This relatively low output probably results from high carbon and sodium impurities in the electrode materials.

INTRODUCTION

Most thermionic converter applications require an emitter that produces large current densities and a collector that yields high voltage. The more promising electrodes expand the utility of these devices for land, sea, and space applications. To be practical the converters should be easy to fabricate from economical materials and should provide long service lives.

In order to develop such a converter, programs to screen and test the numerous promising electrode combinations are necessary.

Traditional research methods are unsophisticated and too costly to achieve such an intensive and massive performance program. With the aid of computers to control, collect, and correlate thermionic diode data (refs. 1 to 10) achievement of these goals became feasible.

The design and fabrication of a miniature guarded planar diode (the diminiode of ref. 11) expanded the capability of the performance program. The evaluation of rare thermionic materials became feasible with this device because of the small size of its electrodes (6 mm or less). Used with a computer facility, the diminiode yields thermionic performance maps with greatly improved quality, quantity, and economy.

The diminiode experiments involved fixed-space (ref. 10) and variable-space (ref. 12) devices. This report summarizes data obtained with a fixed-space diminiode with 110-tungsten electrodes.

The diode was tested at increments between 1700 and 1900 K for the emitter, 694 and 1101 K for the collector, and 519 and 650 K for the reservoir.

PROCEDURE

Diminiode Preparation and Testing

The fixed-gap diminiode (fig. 1) used in the present work had 110-tungsten electrodes with the initial purities indicated in table I. These electrodes were held on their bases with brazes composed of low-vapor-pressure fillers (refs. 12 and 13).

The guarded surfaces of the electrodes (fig. 1(a)) were lapped and polished smooth and flat to 10^{-5} millimeter. This was followed by a cleaning and degassing procedure prior to attachment of the heating and cooling coils by a copper braze. The diminiode was then mounted on a vacuum flange insert (fig. 1(b)), where control and monitor leads and tubes were installed. Next the calibrated cesium-reservoir thermocouples were added along with the collector thermocouples before the system was prepared for vacuum processing (ref. 11).

Finally, the system was baked out and calibrated as described in the next section.

Emitter Temperature Calibration

The temperature of the external tungsten-lined hohlraum was related to that of the black-body hole in the emitter near its surface. The internal hole was viewed through the reservoir tube before the cesium capsule was added. Both cavities had length-to-diameter ratios greater than 5. The calibration included combinations of emitter, collector, and cesium-reservoir temperatures encountered during diminiode testing.

Interelectrode-Spacing Calibration

The present calibration technique for the interelectrode gap is described in reference 12. The spacing between the emitter and the collector is calibrated with cathetometer sightings through the open reservoir before it is filled with cesium and sealed.

For this work, electric zeroing and precision shimming checked by direct observation before vacuum processing fixed the cold interelectrode spacing at 0.23 millimeter. Reference 12 verifies that this measurement also represents the gap at diminiode operating conditions.

Cesium Insertion

The cesium, packaged in a crushable molybdenum capsule, was inserted into the reservoir. The encapsulation procedure is described in reference 11. After the cesium insertion a final bakeout preceded closure of the diminiode by brazing.

Testing

References 10 and 11 describe the stations, instrumentation, procedure, and data presentation for the thermionic performance mapping of diminiodes.

RESULTS AND DISCUSSION

As mentioned in references 1 to 10, the test-cell computer can store and recall output measurements for only a limited number of successive diode-voltage sweeps. Then the data are transmitted to the Lewis central computer for storage on magnetic tape and for some engineering calculations. The manner in which data are stored and displayed is discussed in detail in these references. The computer plots all sorted current, voltage data on parametric composites and displays them on microfilm output. These plots have scales of -0.5 to 2 volts and 0 to 30 amperes per square centimeter.

Table II lists the temperatures at which current, voltage data were obtained for this diminiode with 0.23 millimeter between its 110 -tungsten electrodes. The current, voltage and power, voltage envelopes for the appropriate emitter temperature T_E , collector temperature T_C , and cesium-reservoir temperature T_R appear in figure 2. Points along an envelope for a particular T_E represent varying temperatures of the collector and cesium reservoir. As can be seen in figure 2, a maximum output of 4.5 watts per square centimeter was obtained at an emitter temperature of 1900 K. Performance for four planar converters with 110 -tungsten emitters and collectors of molybdenum and polycrystalline niobium is summarized in reference 12 and presented in figure 3. On the basis of maximum electrode power, the present 110 -tungsten electrode combination (fig. 2) is clearly inferior.

Inherent in the comparison is the assumption that the interelectrode spacings of the four converters correspond to the nominal design value of 0.25 millimeter, that the true emitter surface temperatures are represented by the actual thermal measurements, and that impurities in the test environment were minimal. The interelectrode spacing was somewhat smaller for the diode described in this report, but for the present test conditions it can be assumed that this difference would have only a slight effect on the performance (ref. 14). The analysis of the impurities of the electrodes used in reference 12 are not presented, however.

The monocrystalline tungsten used for electrodes in the present work was selected on the basis of availability at the time the initial diminiode was fabricated. The impurities in this single crystal along with their concentrations are indicated in table I. Compared with the total 0.001 percent impurities of the tungsten emitter of reference 12 the contaminant concentrations of the electrodes for this diminiode

are much higher, particularly those of sodium and carbon. In general, the presence of carbon or sodium on the hot 110-tungsten electrode surfaces tends to reduce their bare work functions, which increases their cesiated work functions and decreases diode outputs. Thus, it is reasonable to assume that the poor performance exhibited by this diminiode is due at least in part to the high carbon and sodium contents indicated in table I.

SUMMARY OF RESULTS

Performance envelopes of the thermionic output from a diminiode having planar electrodes of 110-tungsten surfaces are given in this report.

The performance of this converter was inferior to that obtained with similar planar converters having oriented tungsten emitters and molybdenum and polycrystalline niobium collectors. This inferior performance can be partly attributed to impurities contained in the electrode surfaces.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, March 5, 1974,
502-21.

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TABLE I. - IMPURITY CONCENTRATIONS IN LEWIS

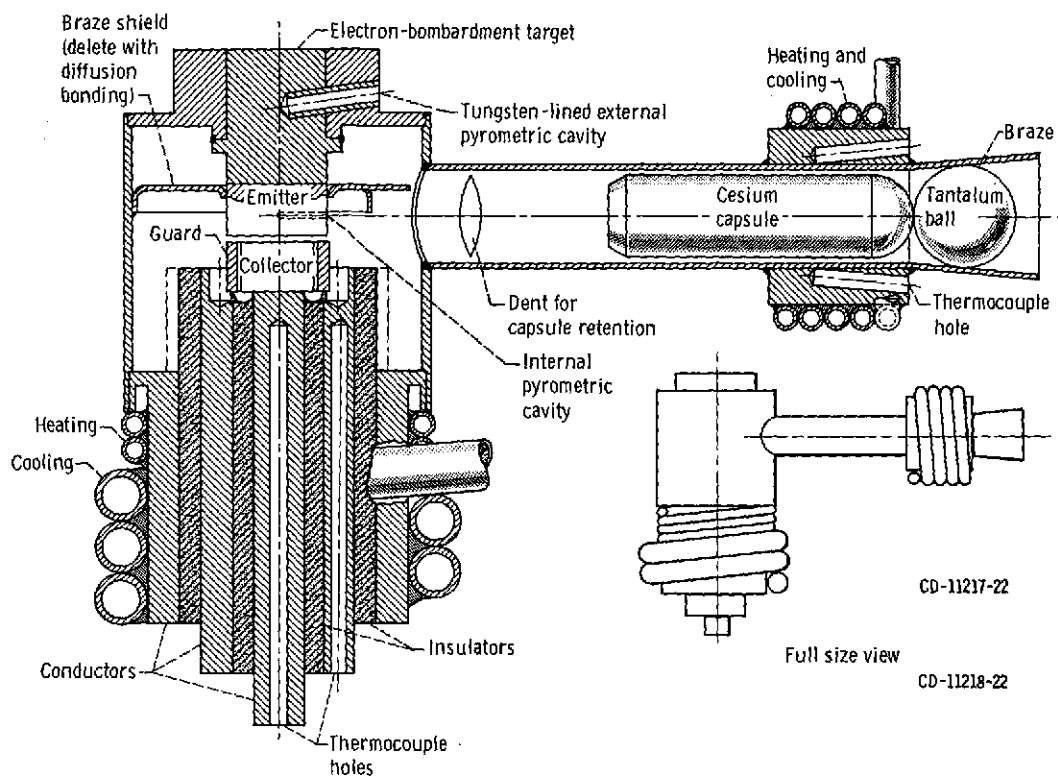
RESEARCH TUNGSTEN

Element	Detection limit, ppm by wt.	Concentration ppm by wt.	Concentration, approximate at. %
Hydrogen	0.01	2.7	-----
Lithium	.001	1.0	-----
Boron	.01	.19	-----
Carbon	.01	230	0.35
Nitrogen	.01	17	-----
Oxygen	.01	110	.13
Fluorine	.01	100	.097
Sodium	.001	200	.16
Magnesium	.01	5.4	-----
Aluminum	.01	32	-----
Silicon	.02	20	-----
Phosphorus	.02	6.1	-----
Sulfur	.02	.54	-----
Chlorine	.02	1.1	-----
Potassium	.002	19	-----
Calcium	.02	2.8	-----
Vanadium	.03	.53	-----
Chromium	.03	15	-----
Manganese	.03	.78	-----
Iron	.05	4.9	-----
Cobalt	.03	2.2	-----
Nitrogen	.05	19	-----
Zinc	.1	.3	-----
Gallium	.05	76	.02
Germanium	.07	4.3	-----
Arsenic	.1	7.7	-----
Molybdenum	.3	120	.023

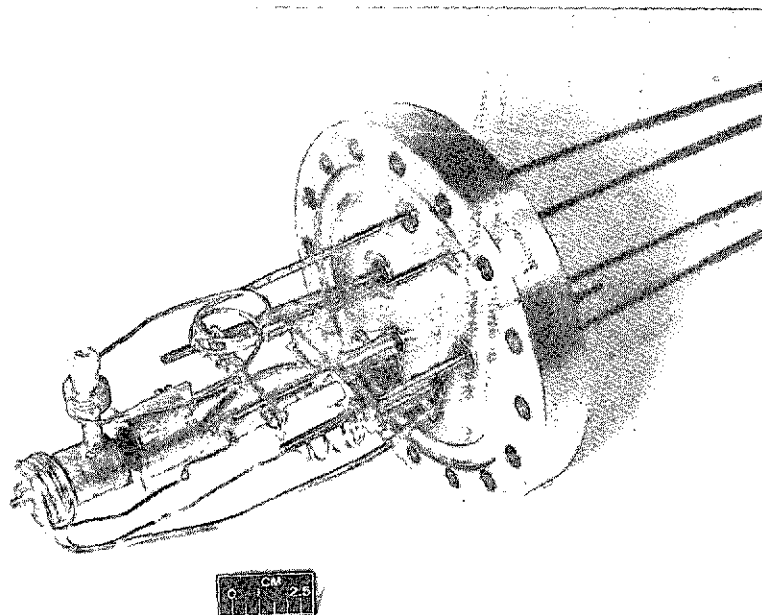
TABLE II. - TEMPERATURE RANGES OF DATA

INCLUDED IN PERFORMANCE MAP

Emitter temperature, T_E , K	Collector temperature, T_C , K	Cesium-reservoir temperature, T_R , K
1700	751 to 1099	519 to 570
1800	694 to 1101	519 to 600
1900	751 to 1100	540 to 650



(a) Cross section.



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(b) Diminiode on vacuum-flange base.

Figure 1. - Fixed-gap diminiode.

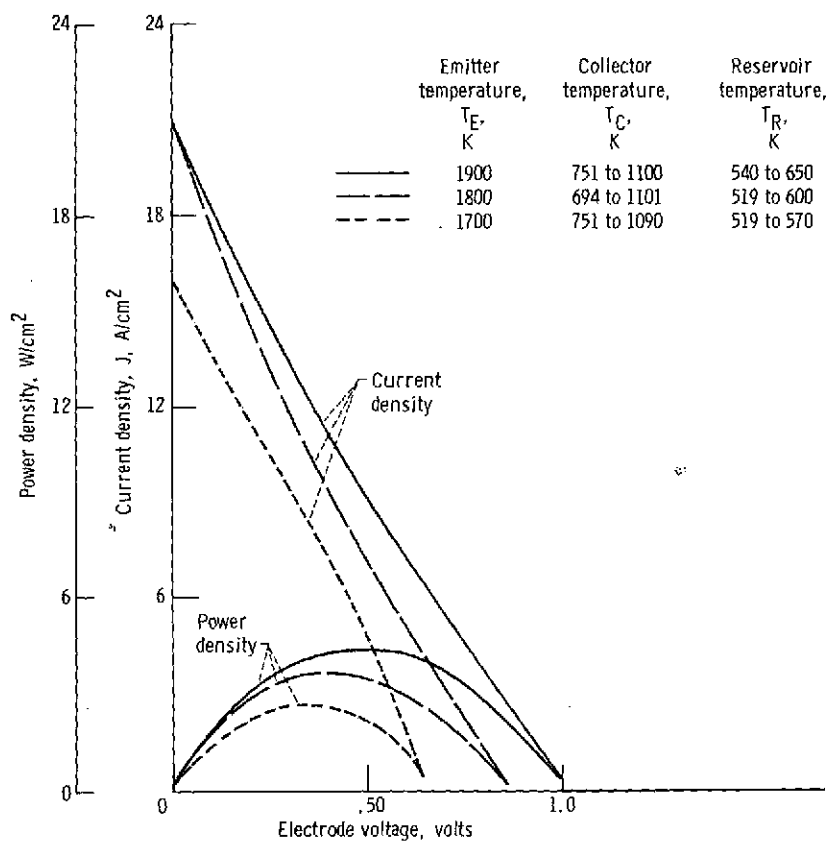


Figure 2. - Envelopes for diiminide with 110-tungsten electrodes at various emitter temperatures.

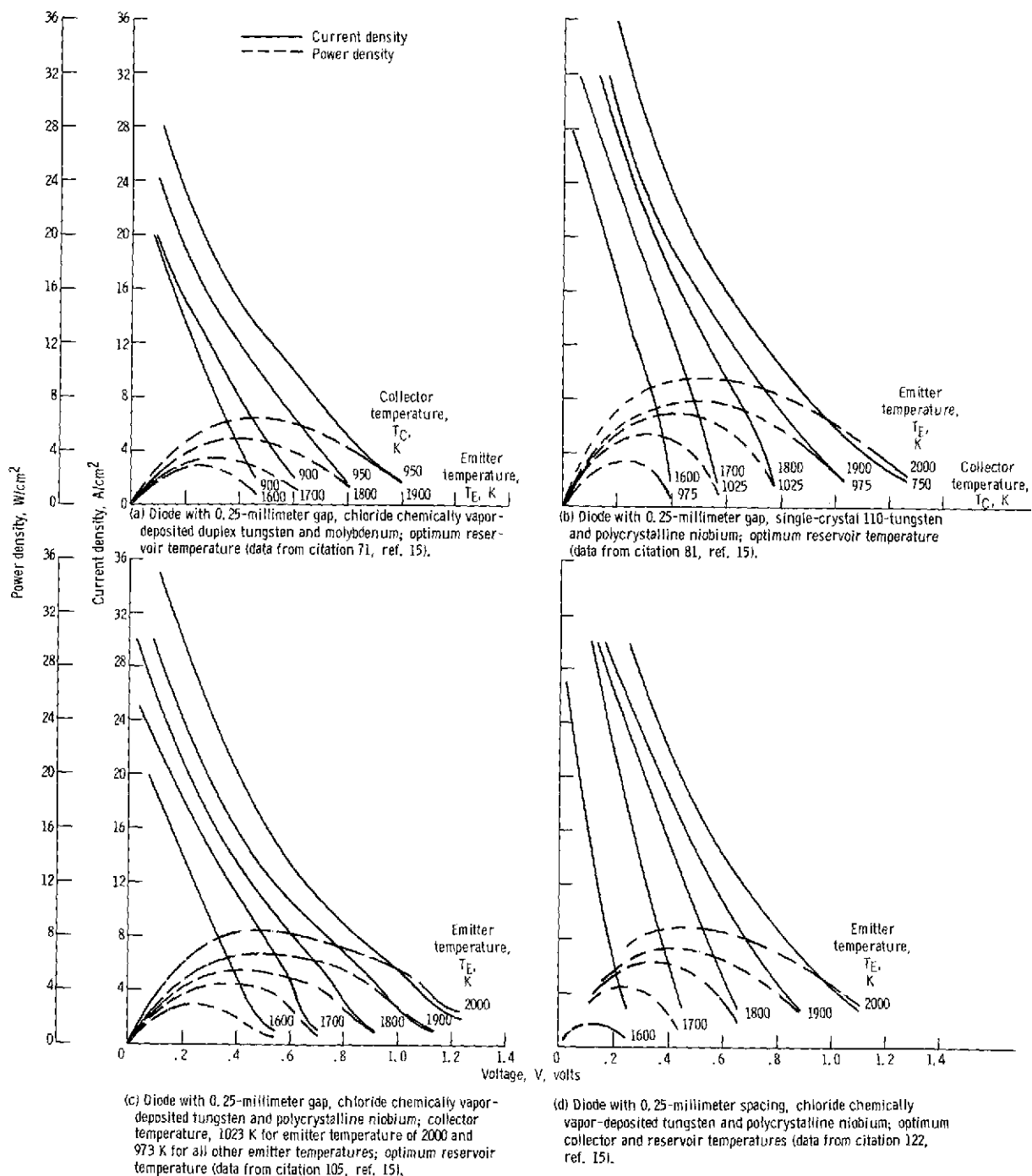


Figure 3. - Envelopes for diodes with near 110-tungsten emitters and near optimum cesium-reservoir temperatures.